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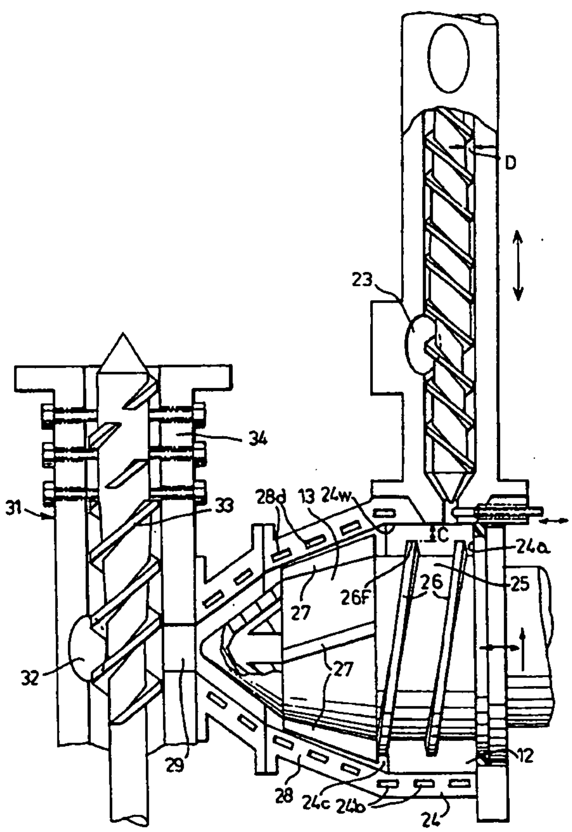
(54) Title: METHOD AND APPARATUS FOR MIXING

(57) Abstract

There is disclosed a method for mixing flowable polymer material with particulate additive, comprising the steps of: a) making a pre-blend of the polymeric material and additive which pre-blend may be inhomogeneous and contain agglomerates; b) compacting and feeding a pre-blend into a first mixing arrangement to form an intermediate blend; c) feeding the intermediate blend into a second mixing arrangement to form a final blend; d) outputting the final blend; at least steps b), c) and d) of the method being carried out as a continuous process.



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METHOD AND APPARATUS FOR MIXING

This invention relates to mixing flowable polymeric material such as rubber or like elastomers with particulate additives, but which may also be adapted or adaptable to other polymers and indeed other material generally.

The rubber industry in particular requires to mix rubber or like elastomeric material with fillers such as carbon black or other additives. Conventionally, the elastomer is supplied in bale form, with a mass of some 20-25 kg. This has resulted in batch mixing operations being standard practice. Attempts have been made to introduce flexible, automated processes based on particulate rubber, but have not to date succeeded on account of both cost and problems with material behaviour.

Some plastics compounding equipment can be used for mixing some particulate rubber compounds, but, in general, elastomers have different characteristics from most thermoplastics and the results are far from optimal, and by no means all rubber elastomers can be processed using such equipment.

The present invention provides methods and apparatus for mixing flowable polymeric material with particulate additives which are suitable for both natural and synthetic rubbers, in particulate form, as well, incidentally, as thermoplastic and thermosetting polymers.

The invention comprises a method for mixing flowable polymeric material with particulate additives, comprising the steps of:

a) making a pre-blend of the polymeric material and additive which pre-blend may be inhomogeneous and contain agglomerates;

b) compacting and feeding a pre-blend into a first mixing arrangement to form an intermediate blend;

c) feeding the intermediate blend into a second mixing arrangement to form a final blend;

d) outputting the final blend;

at least steps b), c) and d) of the method being carried out as a continuous process.

The first mixing arrangement may be a distributive mixing arrangement in which inhomogeneities are reduced. The second mixing arrangement may be a dispersive mixing arrangement in which agglomerates are broken down. However, the first mixing arrangement may be the dispersive mixing arrangement and the second the distributive mixing arrangement.

The polymeric material may itself be in particulate form or it may be in liquid state.

The pre-blend may be made by adding the polymeric material and particulate additive in desired proportions to a hopper from which the pre-blend is fed to the mixing arrangements, but, of course, a previously prepared pre-blend may be added directly to the hopper.

The pre-blend may, however, be fed from the hopper by a screw feeder and compactor arrangements. The screw may have a constant pitch, compaction being achieved by restriction of the exit from the feeder and compactor arrangement, which may comprise a thread-advanced closure member. The screw may have decreasing pitch

or flight depth, however, towards the exit end to achieve or supplement compaction of the pre-blend.

Particulate filler may be added to a thermoplastic polymeric material in a melt screw feeder arrangement feeding the pre-blend to the distributive mixing arrangement. The melt screw feeder arrangement may promote melting of the thermoplastic polymeric material and accommodate an accompanying reduction in volume by reducing in pitch and/or flight depth in the direction of feed. The melt screw feeder arrangement may have an expansion zone at which the melt is decompressed and an inlet into the depressurised melt may be provided for the filler.

The distributive mixing arrangement may comprise a cylindrical chamber with a coaxial rotor, and the pre-blend may be introduced radially at an inlet end of the chamber.

The rotor of the distributive mixing arrangement may have a conveying and mixing screw having substantial clearance between the screw flight and the chamber wall facilitating backflow and decoupling the screw rotation from the feed rate of intermediate blend from the distributive mixing arrangement.

The pre-blend may be heated or cooled in the distributive mixing arrangement, as by passages therein for circulating fluid.

The dispersive mixing chamber may be coaxial with and arranged at the outlet of the distributive mixing chamber - the inlet end of the dispersive mixing chamber may merge with the outlet end of the distributive mixing chamber.

The dispersive mixing arrangement may comprise a blade arrangement rotating in a dispersive mixing chamber with narrow clearance from the chamber wall

whereby the material is subject to elongational flow and shear flow. The dispersive mixing chamber may be conical, tapering towards its outlet, and the cone angle of the blade arrangement may be less than that of the dispersive mixing chamber wall whereby to decrease the blade-to-wall clearance towards the outlet of the chamber.

The cone angle of the blade arrangement may be constant from end to end or may vary from end to end.

The blade arrangement may comprise at least one blade which is (and may indeed comprise several blades which are) angled with respect to the axis of the blade arrangement so as to exert a conveying or pumping action on the intermediate blend being processed in the dispersive mixing arrangement. The blade angle, however, may be such that the conveying or pumping action is not strong enough to exert a dominant influence on the residence time of the intermediate blend in the dispersive mixing arrangement.

The material may be heated by virtue of the mechanical work done on it in feeding it to and/or treating it in the distributive mixing arrangement and this may be supplemented or controlled by additional heating or cooling by heating or cooling means in the dispersive mixing arrangement for example passages for heat exchange fluid.

Heat exchange passages may be provided advantageously in both chamber wall and rotor body in both mixing zones.

The final blend may be output to an extruder, or to a roller die or calendar means to produce sheet material, or, indeed, the dispersive mixing arrangement may output directly through an extrusion die.

Methods and embodiments of apparatus for mixing flowable polymeric materials with particulate additive according to the invention will now be described with reference to the accompanying drawings, in which:-

Figure 1 is an axial section of a first embodiment;

Figure 2 is a section on the line II -II of Figure 1;

Figure 3 is an axial section of a second embodiment;

Figure 4 is an axial section of a third embodiment;

Figure 5 is an axial section of a fourth embodimen; and

Figure 6 is an axial section of a fifth embodiment..

The drawings illustrate methods and apparatus for mixing flowable polymeric materials, such as synthetic elastomers and natural rubbers in particulate form as well as thermosetting plastics, thermoplastics and thermoplastic elastomers, with particulate additives such as carbon black and other, including fibrous, filler materials.

A pre-blend of the polymeric material and additive, which pre-blend may be inhomogeneous and contain agglomerates, is made by adding the components either as an already mixed blend or separately in desired proportions to a hopper 11. The pre-blend is fed into a distributive mixing arrangement 12 in which inhomogeneities are reduced to form an intermediate blend. The intermediate blend is fed into a dispersive mixing arrangement 13 in which agglomerates are broken down to form a final blend, which is then output, the process being carried out on a continuous basis.

The polymeric material may itself be in particulate form, which reflects recent attempts to introduce particulate rubbers to the rubber industry instead of the customary bale which has been the basis of the standard practice of batch processing. Liquid polymer, however, may also be handled by the apparatus.

Figures 1 and 2 illustrate apparatus in which the pre-blend is fed from the hopper 11 to the distributive mixing arrangement 12.

Figure 3 illustrates a horizontal screw feeder and compactor arrangement 18 feeding material from the hopper 11 to the distributive mixing arrangement 12. The screw 19 has constant pitch P and flight depth D and compaction is achieved and controlled by restriction of the exit 21 from the arrangement 18. (The compacted pre-blend may, in the parlance of the rubber industry, be termed "rubber compound" at this stage). The restriction is brought about by an adjustable, thread-advanced closure member 22. If desired, however, additional compaction can be achieved with a screw 19 with progressively decreasing pitch and/or flight depth.

Figure 5 illustrates a screw feeder and compactor arrangement 18 in which the flight depth D reduces towards the exit over a first extent E. In this extent (possibly with added heating) compaction of the polymer (thermoplastic in this case) melts it. An inlet 23 is provided at the end of the extent E where the flight depth D suddenly increases to reduce pressure, allowing filler material to be introduced through inlet 23, after which the material is re-pressurised to be fed to the distributive mixing arrangement 12. Introducing the filler in this way avoids or at least reduces wear problems associated with feeding an abrasive filler together with plastic granules or powder.

The distributive mixing arrangement comprises a cylindrical chamber 24 with a coaxial rotor 25. The pre-blend is introduced radially at an inlet end 24a of the chamber 24. The rotor 25 has a conveying and mixing screw 26 having substantial

clearance C between the screw flight 26F and the chamber wall 24W facilitating backflow and decoupling the pumping or conveying action of the rotating screw 26 from the feed rate of intermediate blend from the distributive mixing arrangement. The pre-blend may well be heated up by the mechanical work done on it in the distributive mixing chamber 24, but cooling or additional heating can be supplied by circulating fluid at an appropriate temperature and flow rate in channels 24b.

The dispersive mixing arrangement 13 comprises a blade arrangement 27 rotating in a dispersive mixing chamber 28 with narrow clearance from the chamber wall 28a whereby the material is subject to elongational flow and shear flow. The chamber 28 is conical, tapering towards its outlet 29, and is coaxial with and arranged at the outlet 24c of the distributive mixing chamber 24.

The blade arrangement 27 is carried on the same rotor 25 as the conveying and mixing screw 26, which is tapered like the chamber 28, but with a lesser cone angle to increase compaction of the material towards the outlet 29. (The cone angle could on the other hand be greater in certain circumstances, or the same as that of the chamber). The blade arrangement 27 has a cone angle which is less than that of the chamber 28 to decrease the blade-to-wall clearance towards the outlet 29 - this, too, could be the same or greater. As illustrated, the blade cone angle is constant from end to end, but could vary, perhaps in order to provide a longer length quite close to the wall of the chamber 28 for more effective dispersion of small agglomerates.

The blade arrangement 27 comprises blades which are angled with respect to the axis of the arrangement so as to exert a conveying or pumping action on the intermediate blend being processed in the dispersive mixing arrangement, but the blade angle is such that the conveying or pumping action is not strong enough to exert a dominant influence on the residence time of the intermediate blend in the dispersive mixing arrangement 13.

The material will be further heated by virtue of the mechanical work done on it in the dispersive mixing arrangement 13. The temperature of the material may be controlled by additional heating or cooling through fluid channels 25d, 28d, to maintain the material at an optimal temperature for processing.

Figure 5 illustrates an arrangement for introducing fibre filler materials into the compound. The output 29 from the dispersive mixing arrangement 13 is into a screw feed arrangement 31 with an inlet port 32 for the fibre filler. The screw 33 decreases in flight depth to feed and compact the rough mix of polymer and fibre, and delivers the rough mix to a pin barrel mixing arrangement 34 for distributive mixing of the fibres. If only fibre is to be used to fill the material, the precise details of the distributive and dispersive mixing arrangements 12, 13 are of less importance.

In all illustrated embodiments, embodiments, the rotor 25 is adjustable towards and away from the outlet 29 to vary the rotor blade-to-chamber wall clearance in the dispersive mixing arrangement to accommodate a wide range of compound types. However, a simple, less expensive construction would have a constant clearance.

Figure 6 illustrates a "budget" version of the mixer in which the rotor 25 is a) not adjustable (or not necessarily adjustable) towards and away from the outlet 29 and b) cylindrical, rather than tapered (except for the end cone 25a). The blades 27 reduce in clearance from the chamber wall towards the outlet 29.

Figures 3 and 6 illustrate the outlet 29 connected to an extruder 35 (which can be vertical, as shown, or horizontal, as in Figure 5), while Figure 4 shows an extrusion die 36 fixed directly on to the outlet 29. A roller die or calendar means could, of course, be connected for the production of sheet material.

For rubber production, a normal feedstock may be a particulate pre-blend of some or all of the ingredients of a rubber compound, possibly with separately metered pelleted polymer and filler. Variables such as temperatures at various stages of mixing, back pressures, as set by various mechanical adjustments and dwell times or throughput rates as they are affected by the speeds of the rollers and screws or rotors as appropriate will all be set to provide optimal throughput rates and rubber properties.

Some compounds, such as silica filled compounds have characteristics which may require two or more stages of mixing, which may be effected by successive passes through the same apparatus, or in a single pass through a succession of connected apparatus.

If the pre-blend has already near uniformity of composition, the distributive mixing arrangement can be dispensed with altogether as such, though, clearly, some redistribution and improvement in uniformity will be achieved at one or both ends of a single dispersive mixing arrangement.

CLAIMS

1. A method for mixing flowable polymer material with particulate additive, comprising the steps of:

a) making a pre-blend of the polymeric material and additive which pre-blend may be inhomogeneous and contain agglomerates;

b) compacting and feeding the pre-blend into a first mixing arrangement to form an intermediate blend;

c) feeding the intermediate blend into a second mixing arrangement to form a final blend;

d) outputting the final blend;

at least steps b), c) and d) of the method being carried out as a continuous process.

2. A method according to claim 1, in which the first mixing arrangement is a distributive mixing arrangement in which inhomogeneities are reduced.

3. A method according to claim 1, in which the second mixing arrangement is a distributive mixing arrangement in which inhomogeneities are reduced.

4. A method according to claim 2 or claim 3, in which the other mixing arrangement is a dispersive mixing arrangement in which agglomerates are broken down.

5. A method according to any one of claims 2 to 4, in which the polymeric material is itself in particulate form.

6. A method according to claim 5, in which the polymeric material is mixed in liquid state.

7. A method according to any one of claims 2 to 6, in which the pre-blend is made by adding the polymeric material to the particulate additive in desired proportion to a hopper from which the pre-blend is fed to the distributive mixing arrangement.

8. A method according to claim 7, in which the pre-blend is fed from the hopper by a screw feeder and compactor arrangement.

9. A method according to claim 8, in which the screw has constant pitch and flight depth and compaction is achieved by restriction of the exit from the feeder and compactor arrangement.

10. A method according to any one of claims 2 to 9, in which particulate filler is added to a thermoplastic polymeric material in a melt screw feeder arrangement feeding the pre-blend to the distributive mixing arrangement.

11. A method according to claim 10, in which the melt screw feeder arrangement promotes melting of the thermoplastic polymeric material and accommodates an accompanying reduction in volume by reducing in pitch and/or flight depth in the direction of feed.

12. A method according to claim 10 or claim 11, in which the melt screw feeder arrangement has an expansion zone at which the melt is depressurised and an inlet into the depressurised melt for the filler.

13. A method according to any one of claims 2 to 12, in which the distributive mixing arrangement comprises a cylindrical chamber with a coaxial rotor, and the pre-blend is introduced radially at an inlet end of the chamber.

14. A method according to claim 13, in which there is an adjustable restriction at the inlet to the distributive mixing arrangement.

15. A method according to claim 13 or claim 14, in which the rotor has a conveying and mixing screw having substantial clearance between the screw flight and the chamber wall facilitating backflow and decoupling the screw rotation from the feed rate of intermediate blend from the distributive mixing arrangement.

16. A method according to any one of claims 2 to 15, in which the pre-blend is heated in the distributive mixing arrangement.

17. A method according to any one of claims 2 to 16, in which the dispersive mixing arrangement comprises a blade arrangement rotating in a dispersive mixing chamber with narrow clearance from the chamber wall whereby the material is subject to elongational flow and shear flow.

18. A method according to claim 17, in which the dispersive mixing chamber is coaxial with and arranged at the outlet of the distributive mixing chamber.

19. A method according to claim 17 or claim 18, in which the dispersive mixing chamber is conical, tapering towards its outlet

20. A method according to claim 19, in which the cone angle of the blade arrangement is less than that of the dispersive mixing chamber wall whereby to decrease the blade-to-wall clearance towards the outlet of the chamber.

21. A method according to claim 20, in which the cone angle of the blade arrangement is constant from end to end.

22. A method according to claim 20, in which the cone angle of the blade arrangement varies from end to end.

23. A method according to any one of claims 17 to 22, in which the blade arrangement comprises at least one blade which is angled with respect to the axis of the blade arrangement so as to exert a conveying or pumping action on the intermediate blend being processed in a dispersive mixing arrangement.

24. A method according to claim 23, in which the blade angle is such that the conveying or pumping action is not strong enough to exert a significant influence on the residence time of the intermediate blend in a dispersive mixing arrangement.

25. A method according to any of claims 2 to 24, in which the material is heated by virtue of the mechanical work done on it in feeding it to and/or treating it in the distributive mixing arrangement.

26. A method according to claim 25, in which heating through mechanical work is supplemented or controlled by additional heating or cooling.

27. A method according to claim 26, in which the additional heating or cooling is from heat exchange with circulating heating fluid in passages around the distributive mixing arrangement.

28. A method according to claim 26, in which additional heating or cooling is supplied at the dispersive mixing arrangement.

29. A method according to any one of claims 26 to 28, in which the additional heating or cooling is controlled to maintain the material at an optimum temperature for processing.

30. A method according to any one of claims 1 to 29, in which the final blend is output to an extruder.

31. A method according to any one of claims 1 to 30, in which the final blend is output to roller die or calendar means to produce sheet material.

32. A method according to any one of claims 1 to 30, in which the final blend is output from the dispersive mixing arrangement directly through a die.

33. Apparatus for mixing flowable polymeric materials with particulate additives, comprising:

a) a hopper for receiving the polymeric material and the additives as a pre-blend;

b) hopper feed-out means to a first mixing arrangement to form an intermediate blend;

c) a second mixing arrangement connected to receive the intermediate blend from the first mixing arrangement to form a final blend;

d) and an output for the final blend.

34. Apparatus according to claim 33, in which the first mixing arrangement is a distributive mixing arrangement in which inhomogeneities are reduced.

35. Apparatus according to claim 33, in which the second mixing arrangement is a distributive mixing arrangement in which inhomogeneities are reduced.

36. Apparatus according to claim 34 or claim 35, in which the other mixing arrangement is a dispersive mixing arrangement in which agglomerates are reduced.

37. Apparatus according to any one of claims 33 to 36, in which the hopper feed-out means comprise screw feeder and compactor means.

38. Apparatus according to claim 37, comprising an adjustable restrictor between the hopper feed-out means.

39. Apparatus according to claim 38, in which said adjustable restrictor comprises a thread-advanced closure member.

40. Apparatus according to claim 38 or claim 39, in which the screw has constant pitch and flight depth and compaction is achieved by restriction by the adjustable restrictor.

41. Apparatus according to any one of claims 37 to 40, in which the screw has decreasing pitch or flight depth towards the exit end to achieve or supplement compaction of the pre-blend.

42. Apparatus according to any one of claims 34 to 41, in which the distributive mixing arrangement comprises a cylindrical mixing chamber with a coaxial rotor.

43. Apparatus according to claim 42, in which the hopper feed-out means open radially into the cylindrical mixing chamber at an input end thereof.

44. Apparatus according to claim 42 or claim 43, in which the rotor has a conveying and mixing screw having substantial clearance between the screw flight and the chamber wall facilitating backflow and decoupling the screw rotation from the feed rate of intermediate blend from the distributive mixing zone.

45. Apparatus according to any one of claims 33 to 44, in which the distribution mixing zone comprises heating means.

46. Apparatus according to claim 45, in which the heating means comprise passages for heating fluid.

47. Apparatus according to any one of claims 33 to 46, in which the dispersive mixing arrangement comprises a blade arrangement rotating in a dispersive mixing chamber with narrow clearance from the chamber wall whereby the material is subject to elongational flow and shear flow.

48. Apparatus according to claim 47, in which the dispersive mixing chamber is conical, tapering towards its outlet.

49. Apparatus according to claim 47 or 48, in which the dispersive mixing chamber is coaxial with an arranged at the outlet of the distributive mixing chamber.

50. Apparatus according to claim 49, in which the dispersive mixing chamber has its inlet end merging with the outlet of the distributive mixing chamber.

51. Apparatus according to any one claims 48 to 50, in which the cone angle of the blade arrangement is less than that of the dispersive mixing chamber wall whereby to decrease the blade-to-wall clearance towards the outlet of the chamber.

52. Apparatus according to claim 51, in which the cone angle of the blade arrangement is constant from end to end.

53. Apparatus according to claim 51, in which the cone angle of the blade arrangement varies from end to end.

54. Apparatus according to any one of claims 47 to 53, in which the said blade arrangement comprises at least one blade which is angled with respect to the axis of the blade arrangement so as to exert a conveying or pumping action on the intermediate blend being processed in the dispersive mixing arrangement.

55. Apparatus according to claim 54, in which the said blade angle is such that the conveying or pumping action is not strong enough to exert a significant influence on the residence time of the intermediate blend in the dispersive mixing arrangement.

56. Apparatus according to any one claims 47 to 55, in which the dispersive mixing arrangement has heating or cooling means.

57. Apparatus according to claim 53, in which the heating or cooling means comprise passages for heat exchange fluid.

58. Apparatus according to any one of claims 33 to 57, comprising an extruder attached to the output of the dispersive mixing arrangements.

59. Apparatus according to any one of claims 33 to 58, comprising a roller die or calendar means attached to the output of the dispersive mixing arrangement.

60. Apparatus according to any one of claims 33 to 53, in which the output of the dispersive mixing arrangement comprises an extrusion die.

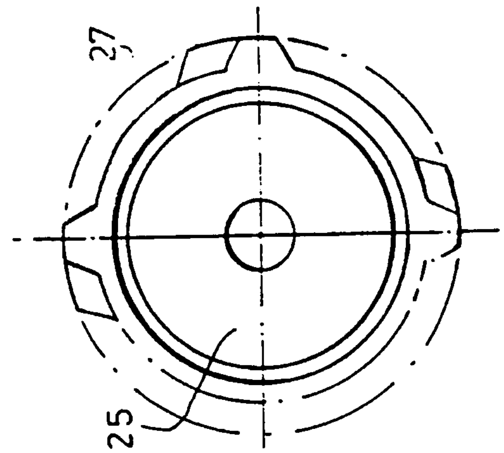
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FIG.2

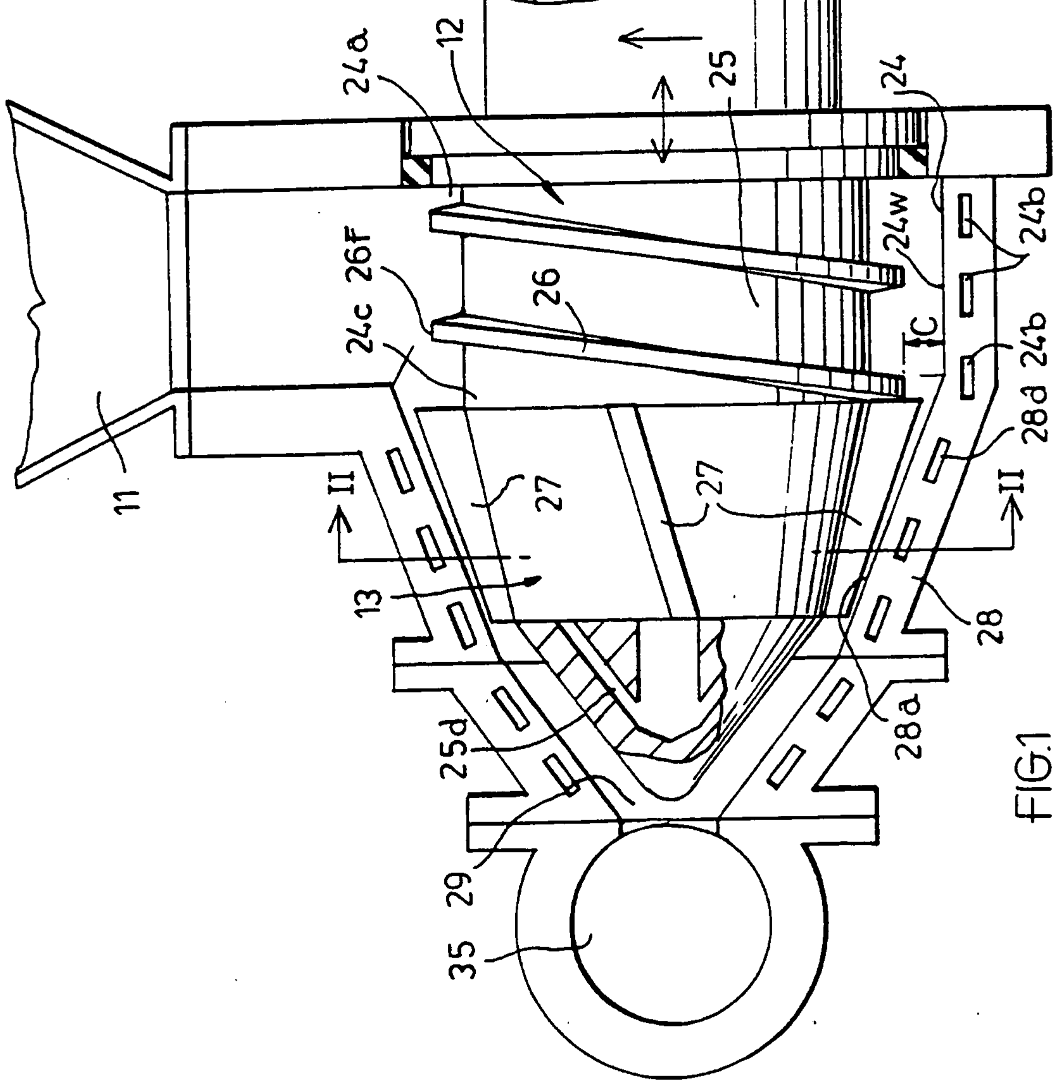
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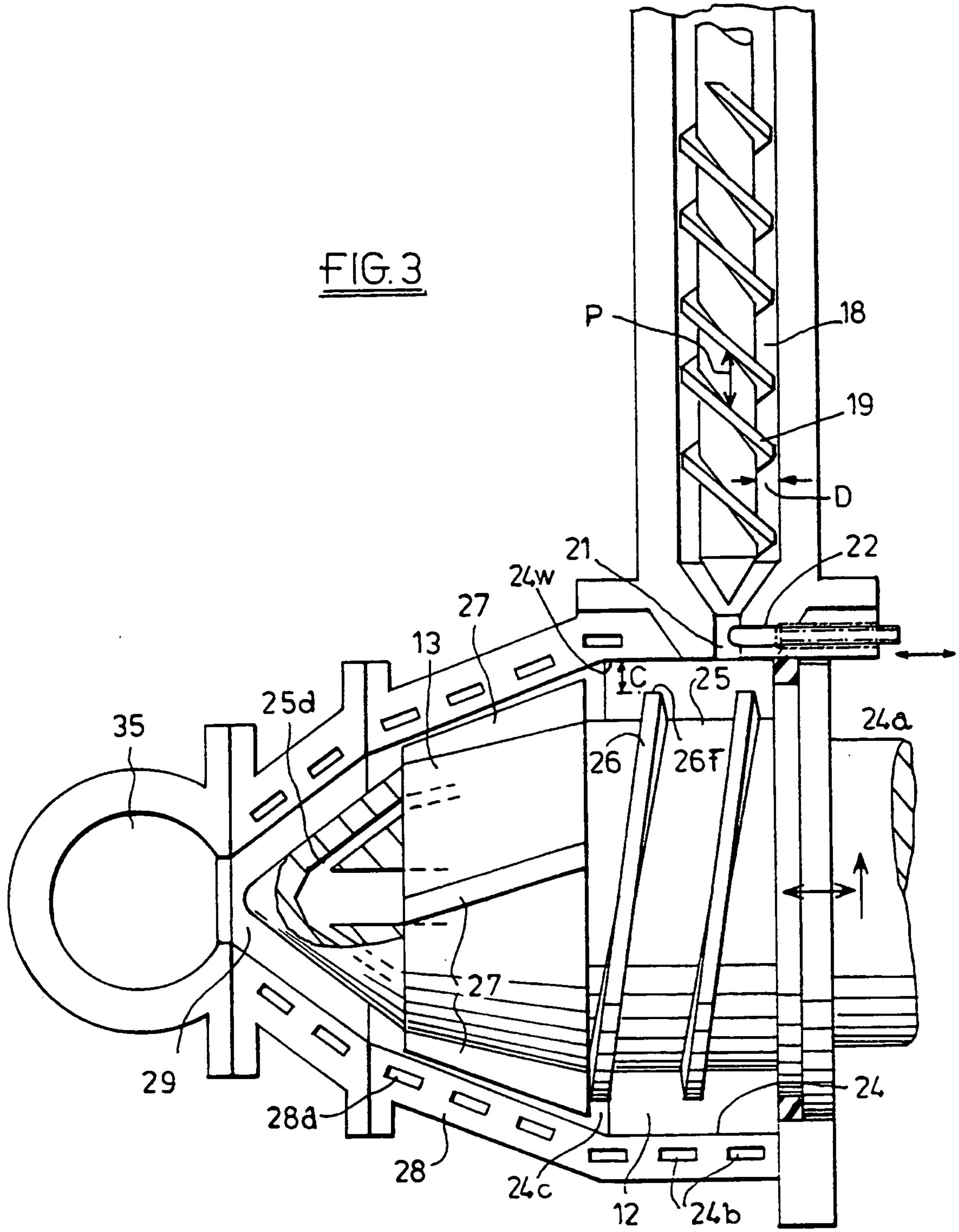
FIG.1

FIG. 3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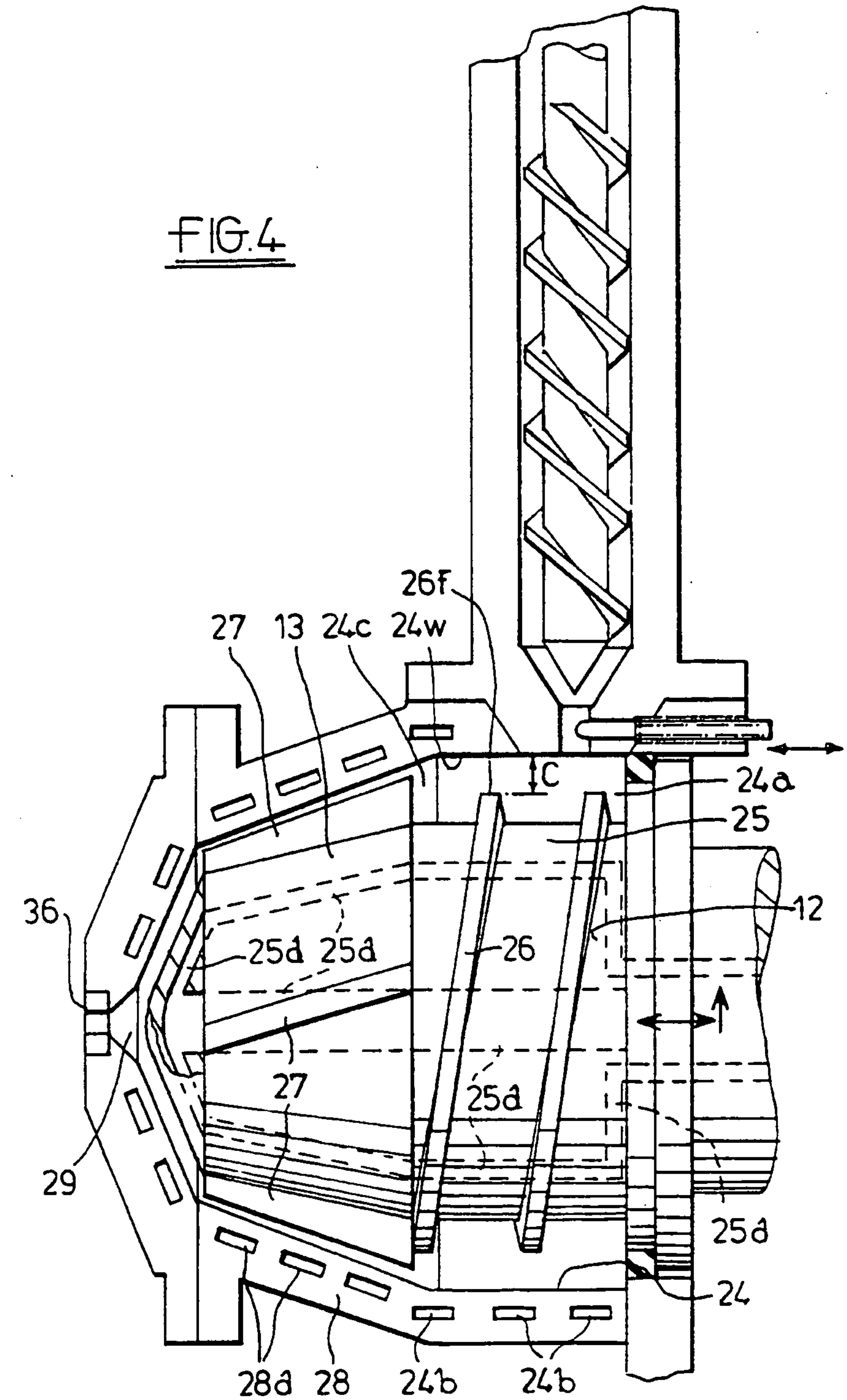
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FIG.6

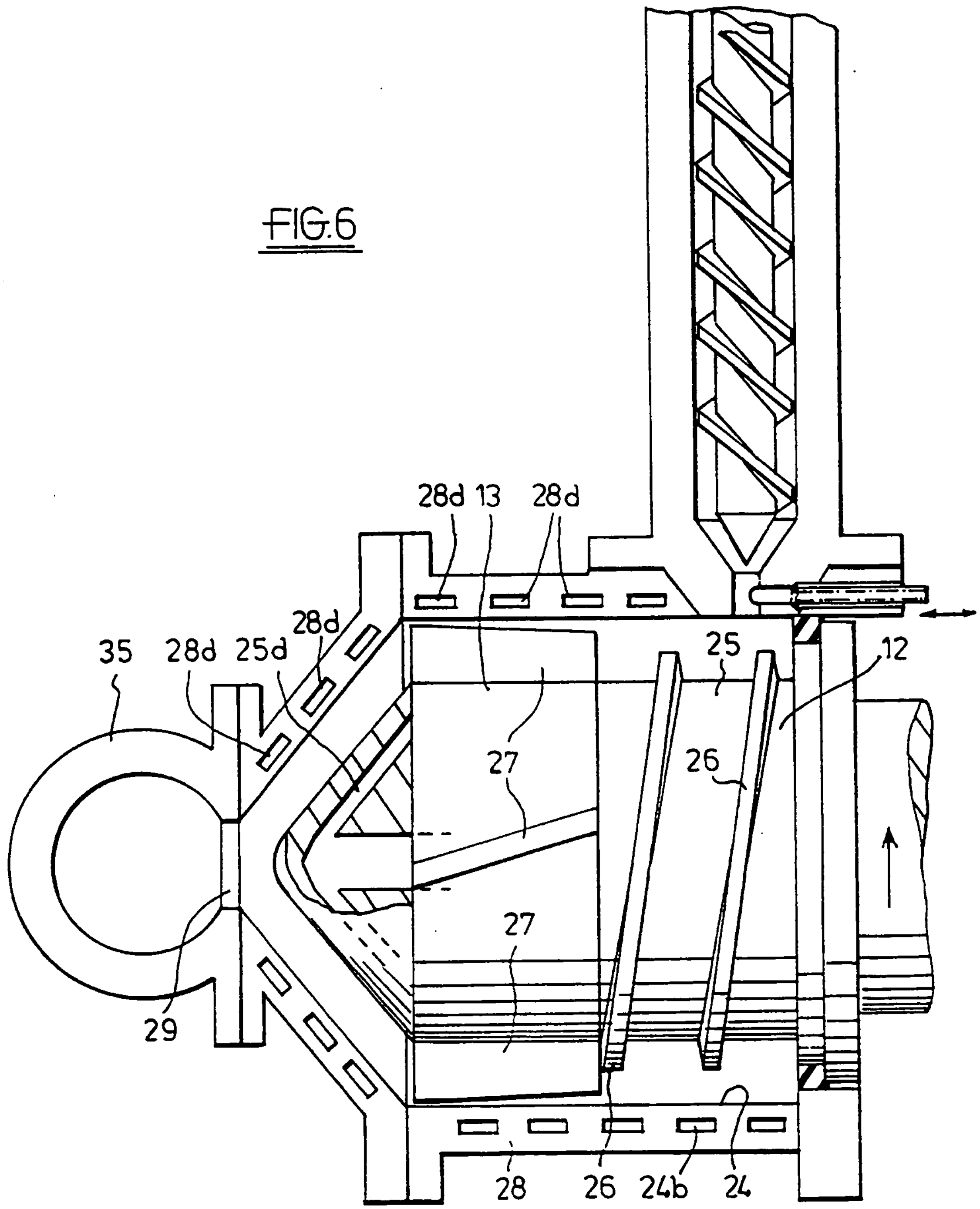
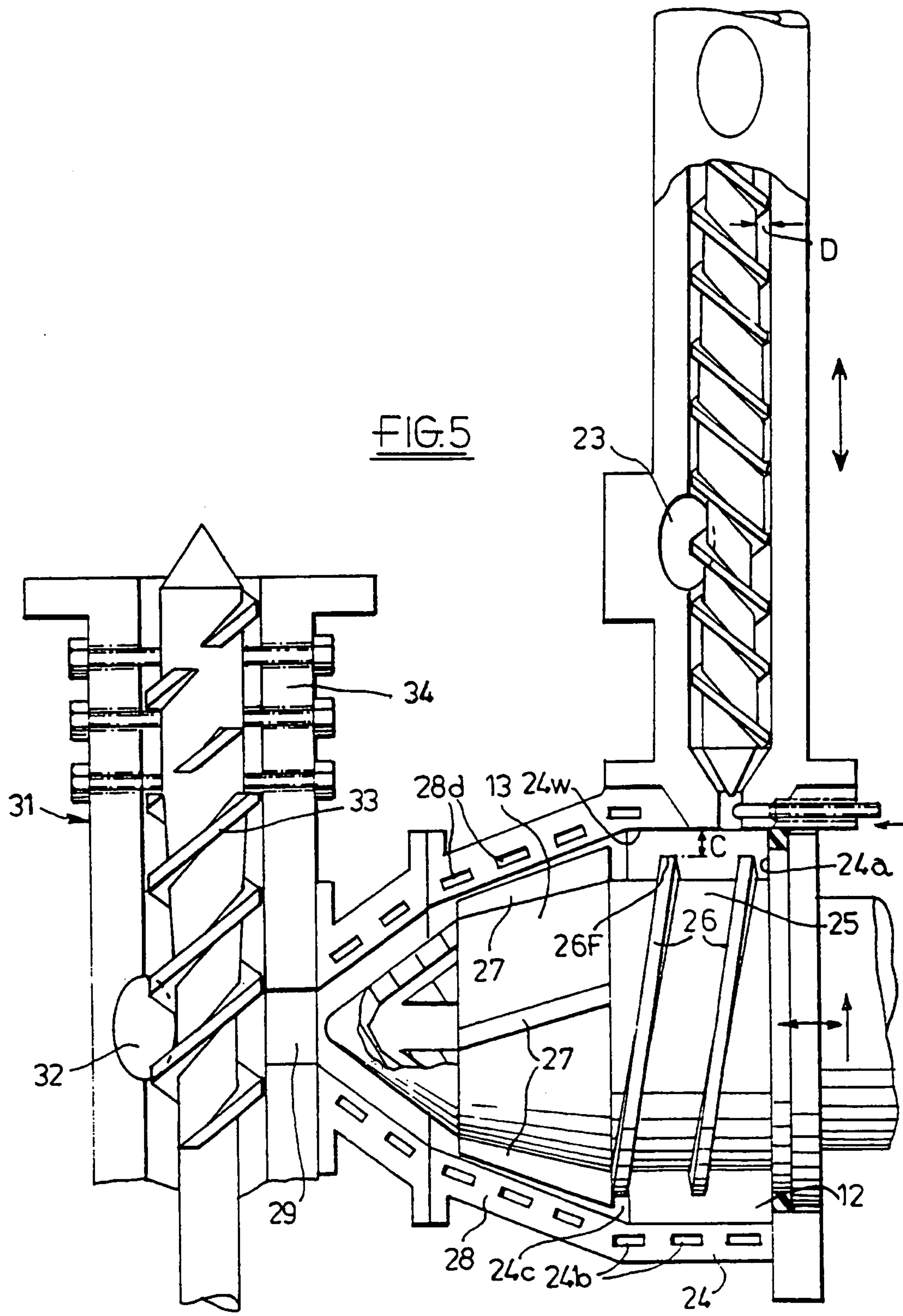


FIG.5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INTERNATIONAL SEARCH REPORT

International Application No
PCT/GB 99/00768

A. CLASSIFICATION OF SUBJECT MATTER
IPC 6 B29C47/50

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 6 B29C B01F

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	DATABASE WPI Section Ch, Week 9212 Derwent Publications Ltd., London, GB; Class A32, AN 92-093879 XP002106873 & JP 04 039022 A (MITSUBISHI HEAVY IND CO LTD), 10 February 1992 see abstract	1-12, 33-37
A		13-24, 41-44
X	PATENT ABSTRACTS OF JAPAN vol. 011, no. 086 (M-572), 17 March 1987 & JP 61 241117 A (JAPAN STEEL WORKS LTD:THE), 27 October 1986 see abstract	13-16
A		25-32, 42-60

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[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

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22 June 1999	01/07/1999

Name and mailing address of the ISA	Authorized officer
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INTERNATIONAL SEARCH REPORT

Internat' Application No
PCT/GB 99/00768

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A	US 4 958 770 A (MITCHELL WILLIAM S) 25 September 1990 see the whole document ---	1-13, 33-36
A	US 4 416 543 A (BRINKMANN HEINZ) 22 November 1983 see abstract see claims; figures ---	1-13, 33-37
A	US 4 897 236 A (RAEBIGER NORBERT ET AL) 30 January 1990 see abstract see figures see column 8, line 4 - line 9 see column 11, line 4 - line 6 see claims -----	14,15, 38,39

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